TRANSITION FROM IGNITION TO FLAME GROWTH UNDER EXTERNAL RADIATION IN THREE DIMENSIONS (TIGER-3D)

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This study focuses on localized ignition by external radiant flux and subsequent flame growth over thin polymeric materials (plastic and paper) in microgravity. Two transition stages were observed. The first transition stage covers the period from the onset of ignition to the formation of stabilized flame near the ignited area. This is followed by the second transition of the flame growth stage from the initial stabilized flame to sustained fire growth away from the ignited area. For the first stage, ignition experiments of thin PMMA sheets were conducted using a CO_2 laser as an external source in the 10 s drop tower. The results of front side surface ignition and of backside surface ignition were observed. The effects of imposed flow velocity, sample thickness, and ambient oxygen concentration on ignition are obtained. Numerical study was conducted to investigate to understand and predict ignition behavior observed in the experiments. For the second stage, numerical study is being conducted to describe the effects of gravity on heat release rate of a PMMA sheet. The gravity level was varied from zero to normal gravity. The preliminary results show that the maximum heat release occurs at around 0.02 g.

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Transition from Ignition to flame Growth under External Radiation in 3D

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Objectives

- **Understand localized ignition processes of polymeric materials (plastic and paper) and subsequent flame growth in microgravity.**
- **Determine the effects of gravity (from 0 g to normal g)**
- **Determine the effects of sample thickness**
- **Determine the effects of imposed flow velocity**
- **Determine the effects of oxygen concentration at various atmospheric pressures**

Approach

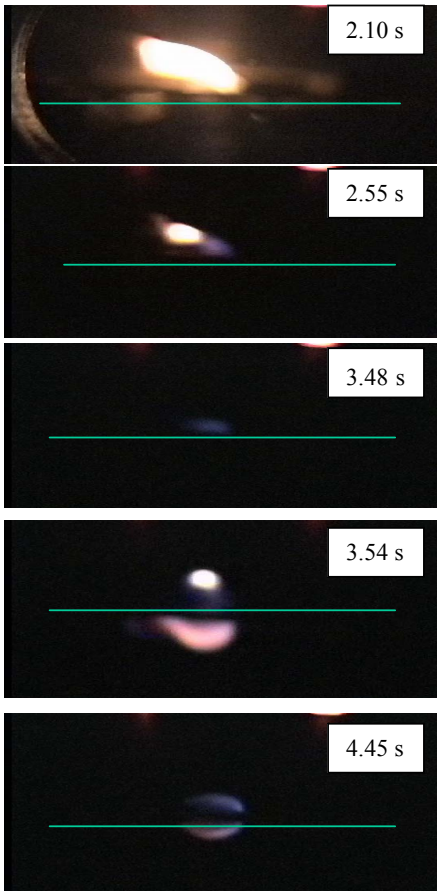
- **Two transition stages**
  - **First transition stage**: From onset of ignition to formation of anchored flame
  - **Second transition stage**: Flame growth from localized, anchored flame
- **First transition stage**: Experiments in the 10 s drop tower at JAMIC and 3 D numerical calculation.
- **Second transition stage**: Numerical calculation.

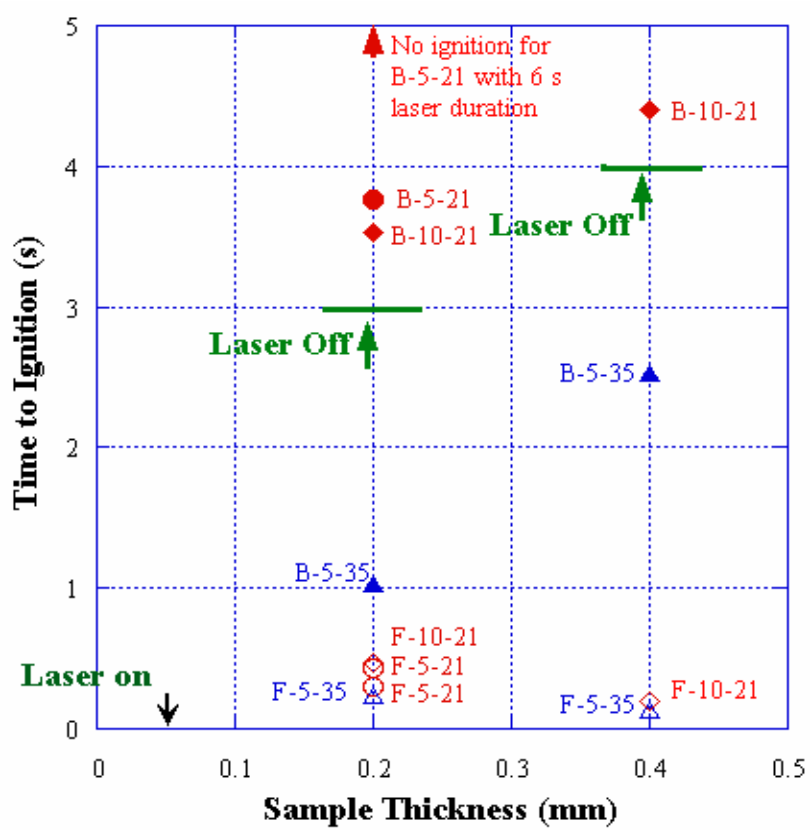
Experiments

- CO_2 laser as an external radiant source
- PMMA(0.2 mm & 0.4 mm thick) and Paper (60 g/m2, 120 g/m2, and 240 g/m2)
- Air and 35% O2/65%N2
- Imposed flow velocity (up to 20 cm/s)

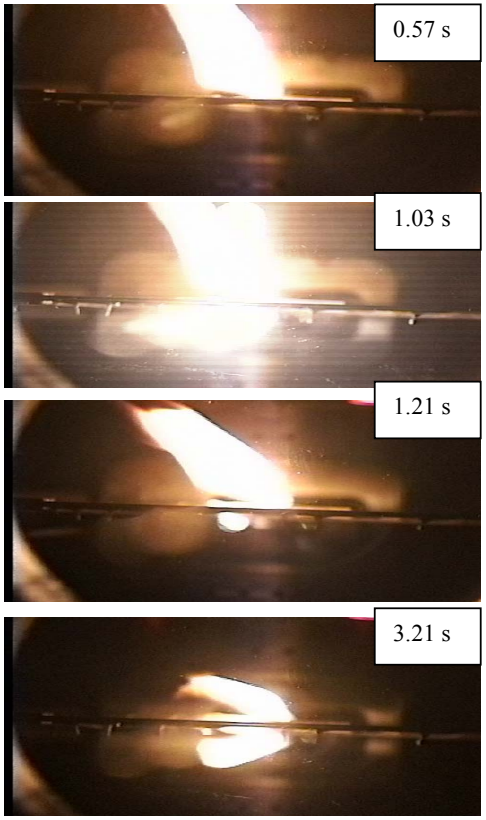
Numerical Calculation

- 3-D time-dependent Navier-Stokes equations



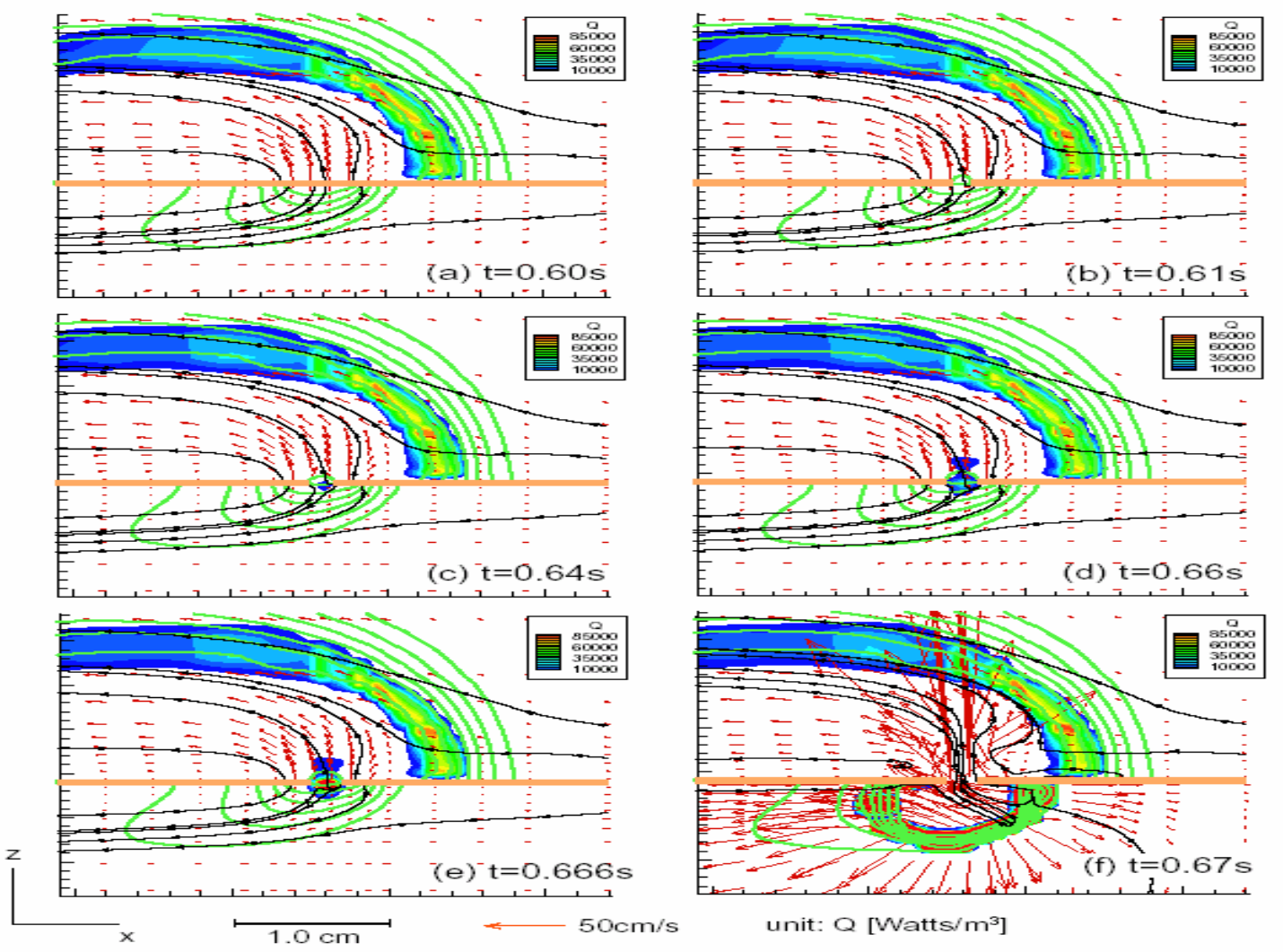


PMMA(0.2mm), air, 5cm/s from right



PMMA(0.2mm), 35% O_2 at 5 cm/s from right

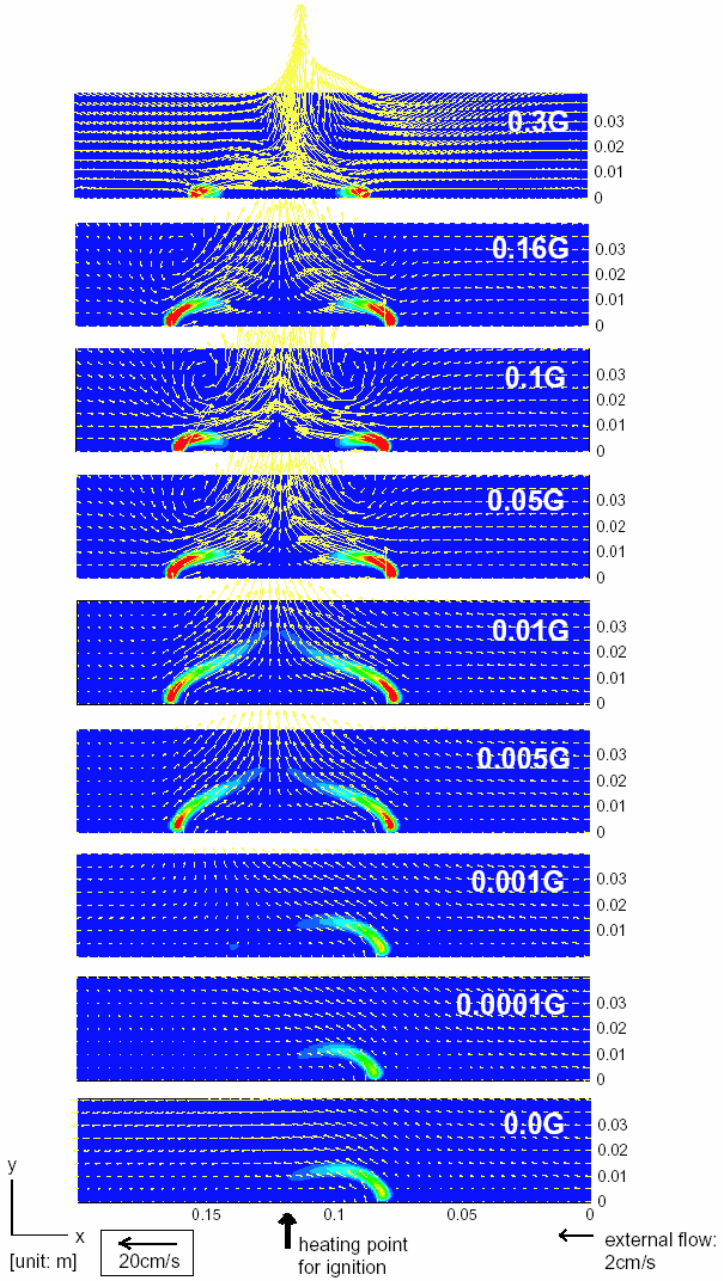
PMMA(0.2mm), air at 5 cm/s with 6 s laser duration. t=0.06 s before laser termination

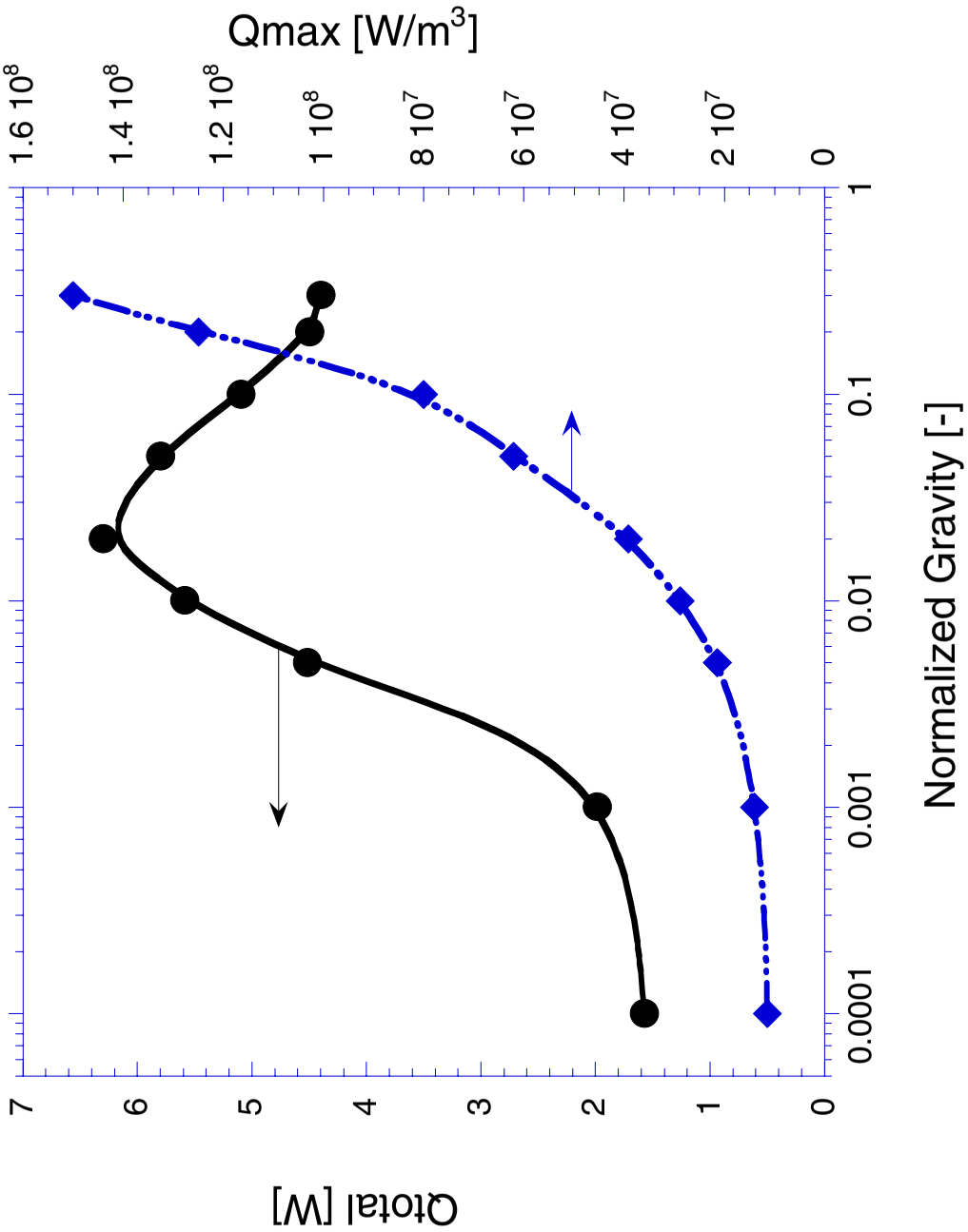


Numerical results: heat release rate (Q), oxygen mass fraction (green), stream line (black), flow vectors (red arrow), PMMA (orange sheet)

Second Transition Stage

- **Effects of gravity on flame growth and heat release rate – Preliminary results**


0.3G
0.16G
0.1G
0.05G
0.01G
0.005G
0.001G
0.0001G
0.0G
0.03
0.02
0.01
0
0.15
0.1
0.05
y
x
[unit: m]
20cm/s
heating point
for ignition
external flow:
2cm/s


Qmax [W/m3]
1.6 10^8
1.4 10^8
1.2 10^8
1 10^8
8 10^7
6 10^7
4 10^7
2 10^7
0
Qtotal [W]
7
6
5
4
3
2
1
0
0.0001
0.001
0.01
0.1
1
Normalized Gravity [-]